10/588381
IAP11 Rec'd PCT/PTO 02 AUG 2006

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re patent application of

Gerrit WOLK

Corres. to PCT/EP2005/001032

For: DEVICE FOR HEAT EXCHANGER AND METHOD FOR PRODUCING ONE SUCH DEVICE

VERIFICATION OF TRANSLATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

I, Charles Edward SITCH,

Deputy Managing Director of RWS Group Ltd UK Translation Division, of Europa House, Marsham Way, Gerrards Cross, Buckinghamshire, England declare:

That the translator responsible for the attached translation is familiar with both the German and the English language, and that, to the best of RWS Group Ltd knowledge and belief, the attached English translation of International Application No. PCT/EP2005/001032 is a true, faithful and exact translation of the corresponding German language paper.

I further declare that all the statements made in this declaration of my own knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of legal decisions of any nature based on them.

July 21, 2006

Date

Name: Charles Edward SITCH
Deputy Managing Director
For and on behalf of RWS Group Ltd

Device for heat exchange and method for producing one such device

The present invention relates to a heat exchanger for a high-pressure cooling circuit, and in particular to a high-pressure cooler, specifically a high-pressure gas cooler, and/or a high-pressure auxiliary heater.

The expression high-pressure cooling circuit is used below to denote a cooling circuit, in which a fluid flowing through the cooling circuit, at least in sections, is at an operating pressure in the order of approximately 110 bar to 130 bar, and in particular approximately 125 bar, and/or which cooling circuit is required in accordance with the currently applicable safety regulations to be designed for bursting pressures in a range from 270 bar to 360 bar.

Heat exchangers of this kind used in high-pressure cooling circuits, referred to below in abbreviated form as high-pressure heat exchangers, are already familiar from the prior art.

Fig. 10 depicts a section through a high-pressure heat exchanger of this kind, in this case a two-row heat exchanger, and/or a two-row high-pressure gas cooler familiar from the prior art.

In the two-row high-pressure heat exchanger or high-pressure gas cooler in accordance with the prior art, tubes 1000 are arranged on two parallel levels. The tubes arranged in each case on one level are, for their part, also aligned parallel with one another.

In accordance with the prior art, the tubes 1000 exhibit a flat tubular form, which in its cross

section 1001 exhibits a long side 1002 and a significantly shorter side 1003 in relation to this long side 1002.

A cooling medium flows through the (flat) tube 1000 in a longitudinal direction 1004, for which purpose a plurality of flow channels 1005 are provided as a rule in the flat tube 1000 running essentially parallel with the longitudinal direction 1004 and/or with a longitudinal axis of the flat tube 1000.

The cooling medium, at least in this section, is at an operating pressure of approximately 125 bar. In accordance with the applicable safety regulations, however, the high-pressure heat exchanger and/or the high-pressure gas cooler is designed for bursting pressures in the range from 270 bar to 360 bar.

In end sections 1009 at both ends 1008 of the flat tube 1000, the flat tube 1000 exhibits in each case in accordance with the prior art a continuous twist or torsion of up to 90° about its longitudinal axis.

In accordance with the prior art, both ends 1007 of the flat tube 1000 that are twisted through 90° in this way are connected in a liquid-tight and/or gas-tight manner to collection devices and/or distribution devices 1008 in the form of hollow bodies.

The expression connection to one another is used to denote a connection of a kind such that a fluid in liquid and/or gaseous form, for example the cooling medium, is able to flow through this connection in a liquid-tight and/or a gas-tight manner.

The long side 1002 of the cross section 1001 of

the flat tube 1000 runs essentially parallel with a longitudinal axis (principal direction of extension) of the collection device and/or the distribution device 1008 in the form of a hollow body at a connection point between one end of the flat tube 1000 and the collection device and/or the distribution device 1008 in the form of a hollow body.

On the basis of the twisting of the ends 1007 of the flat tubes, an inner dimension of the collection device and/or the distribution device 1008 in the form of a hollow body, i.e. an internal cross section of the collection device and/or the distribution device 1008 in the form of a hollow body, can be reduced and with it the material thickness. The bursting pressures stipulated in accordance with the safety regulations and the prevailing operating pressures can be achieved in this way in return for reduced material thicknesses and material costs for the collection device and/or the distribution device 1008 in the form of a hollow body.

However, the twisting of the ends 1007 of the flat tubes reduces a surface of the flat tube 1000 that is capable of being used for the exchange of heat, and in particular a surface for cooling, in a disadvantageous manner, and with it an end surface of the high-pressure heat exchanger capable of being used for cooling.

Furthermore, the twisting of the ends 1007 of the flat tubes restricts the free choice of a distance 1010 for the parallel mutual separation 1010 of the flat tubes 1000 in a disadvantageous manner. A corrugated rib height for the heat exchanger or the gas cooler is limited to a minimum height in this way.

The twisting of the ends 1007 of the flat tubes

also restricts the transverse subdivision of a heat exchanger matrix of the gas cooler in a disadvantageous manner.

The twisting of the ends 1007 of the flat tubes also increases the manufacturing costs involved in the manufacture of the flat tubes.

A similar situation or a similarly disadvantageous situation also applies in particular in the case of high-pressure auxiliary heaters that are familiar from the prior art and in the case of high-pressure heat exchangers in general that are familiar from the prior art.

The object of the present invention is accordingly to make available a high-pressure heat exchanger that is more economical in respect of its manufacture and is subject to fewer restrictions in its geometry, including in the presence of smaller material thicknesses compared with the prior art.

This is achieved in accordance with the invention by the device for the exchange of heat and by the method for producing a device for the exchange of heat having the characterizing features in accordance with the independent patent claim in each case.

Advantageous embodiments and further developments are the subject of the dependent claims.

The device in accordance with the invention for the exchange of heat exhibits at least one flow device and at least one collection and/or distribution device connected to the at least one flow device at a connection point.

The expression connection to one another is used to denote a connection of a kind such that a fluid in liquid and/or gaseous form, for example a cooling medium, in particular carbon dioxide, is able to flow through this connection in a liquid-tight and/or gas-tight manner under high pressure, for example at an operating pressure of approximately 110 bar to 130 bar, and in particular approximately 125 bar.

The flow device in accordance with the invention exhibits a predetermined length (flow device length) and a flat tubular cross section.

The expression flat tubular cross section (flat tube) is used in the context of the invention to denote a cross-sectional form which exhibits a long side (depth) and a significantly shorter side (height) in relation to this long side.

A fluid under high pressure, for example an operating pressure of approximately 110 bar to 130 bar, and in particular approximately 125 bar, flows through the flow device and the collection and/or distribution device.

The flow device in accordance with the invention exhibits a linear course over the entire length of the flow device along a longitudinal axis of the flow device.

In this case, the expression linear course along the longitudinal axis is used to denote a course, in which the flow device or the flat tubular cross section of the flow device is neither twisted nor wound about the longitudinal axis, and in which the longitudinal axis itself does not exhibit a bent or curved course.

The long side of the flat tubular cross section of the flow device, also referred to in the following as the (flow device) depth, exhibits a length of approximately 5 mm to 6.1 mm, and in particular 5 mm to 5.9 mm.

At the connection point, the long side of the flat tubular cross section of the flow device exhibits an angle of approximately 90° in relation to a principal direction of extension of the collection and/or distribution device.

The device in accordance with the invention for the exchange of heat and the flow device in accordance with the invention are based on the not insignificant finding that, in the case of cross-sectional depths of the flow device in the order of approximately 5 mm to 6.1 mm, and in particular in the order of 5 mm to 5.9 mm, it is possible to dispense with twisting of the cross section at the ends of the flow device.

If the linear flow device is now connected to a collection and/or distribution device in such a way that the long side of the flat tubular cross section of the flow device exhibits an angle of approximately 90° in relation to the principal direction of extension of the collection and/or distribution device, bursting pressures above the stipulated 270 bar can be reached or achieved with the device in accordance with the invention, including in the case of reduced material thicknesses, and/or these can also be operated in a high-pressure range in the case of reduced material thicknesses.

In the method for producing a device for the exchange of heat, a connection is produced at a

connection point between at least one flow device and at least one collection and/or distribution device, which connection is taken from a group that contains soldered, welded or adhesive bonded connections.

The at least one flow device is preferably pushed and/or soldered into the at least one collection and/or distribution device.

The expression connection is used here to denote connection of a kind such that a fluid in liquid and/or gaseous form, for example a cooling medium, is able to flow through this connection in a liquid-tight and/or gas-tight manner under high pressure, for example at an operating pressure of approximately 125 bar.

The flow device and the collection and/or distribution device exhibit the specification outlined above.

Thanks in particular to the ability afforded by the invention to dispense with the twisting of the cross section of the flow device, referred to below in abbreviated form as tube twisting or flat tube twisting in the high-pressure area, this and the embodiments and further developments of this exhibit advantages.

It is thus possible, through the linear flow device in accordance with the invention, to achieve a more generously ribbed end surface of relevance to the exchange of heat than in the case of a comparable, twisted flow device.

There is also no need, in the case of a parallel arrangement of a plurality of flow devices in accordance with the invention, in particular (flat)

tubes, on a single level, to maintain any minimum distance between two of the flow directions in each case. Corrugated ribs between neighboring flow directions are thus capable of being achieved with smaller overall heights.

Moreover, the costs incurred for production in the case of the flow devices in accordance with the invention are lower than in the case of comparable, twisted flow devices.

In the same way, the invention makes possible a lower consumption of material and accordingly lower material costs compared with conventional, multi-row heat exchangers.

Handling of the linear flow devices in the production of high-pressure heat exchangers, in particular high-pressure coolers and/or high-pressure auxiliary heaters, is also simplified, in particular in the case of a tube supply for assembly in the form of a cassette.

Moreover, collection and/or distribution devices with a simpler geometry, which are connected to the flow devices at their untwisted ends, are also capable of being achieved.

In a preferred embodiment, the flow device, for example a flat tube, exhibits a height or a cross-sectional height in the order of approximately 1 mm to 2 mm and/or a length in the order of approximately 200 mm to 800 mm. The expression height is used here to denote the above-mentioned significantly shorter side of the flat tubular cross section in relation to the long side, i.e. the depth. An internal admission height of a duct inside the flat tube preferably lies between

0.4 mm and 1 mm in this case.

In a further preferred embodiment, the flow device exhibits at least one internal flow channel running essentially parallel with the longitudinal axis of the flow device, and preferably a plurality of internal flow channels running essentially parallel with the longitudinal axis.

In its cross section, the at least one flow channel can exhibit a form which is essentially circular or elliptical, polygonal or rectangular, or a combination of mixed forms of these, for example rectangular with more or less strongly rounded corners.

At least one medium (fluid) with the ability to flow, such as a cooling medium, flows through the at least one flow channel, at least in sections, at an operating pressure of approximately 125 bar.

The expressions mediums with the ability to flow or fluids with the ability to flow are used in the context of the invention to denote mediums in liquid and/or gaseous form of any desired viscosity, in particular, although not exclusively, oils, fluids, in particular with a high vaporization heat, water, air or gases, for example carbon dioxide, as well as cooling mediums, which possess the ability to evaporate or condense. What is more, the mediums with the ability to flow can also contain additives for the purpose of preventing corrosion.

A recess can be provided on the collection and/or distribution device side for a connection of the flow device at the connection point. A cross section through this recess is adapted in this case to the flat tubular cross section of the flow device. In addition,

the recess can exhibit supplementary formed areas, which serve the purpose, for example of guide tapers for flat tubes.

In a further preferred embodiment, the collection and/or distribution device exhibits a tubular cross section. An internal diameter of the tubular cross section of the collection and/or distribution device is preferably approximately equal to the (cross sectional) depth of the flow device.

The device in accordance with the invention is particularly suitable for a high-pressure heat exchanger, in particular a high-pressure cooler, specifically a high-pressure gas cooler, and/or a high-pressure auxiliary heater.

A heat exchanger of this kind exhibits a plurality, as a rule a large number, of flow devices in accordance with the invention, such as flat tubes, which are arranged on at least one level essentially parallel with one another and at a predetermined distance.

Ribs or corrugated ribs can be arranged in each case between two neighboring flow devices on one level, preferably in a single row. The height of a corrugated rib can be in the order of approximately 2 mm to 8 mm. The corrugated ribs on one level can also be separate corrugated ribs.

Alternatively, a corrugated rib extending continuously over a plurality of levels can be provided.

In the heat exchanger, furthermore, the plurality of flow devices are connected in each case in

a liquid-tight and/or gas-tight manner to a collection and/or distribution device at least at one end at a connection point.

The plurality of flow devices are preferably arranged on two levels, in conjunction with which in each case the ends of the flow devices are connected on one level to a collection and/or distribution device.

In a further embodiment, the flow devices on two neighboring levels can also be offset in relation to one another.

In a further preferred embodiment of a cooler and/or an auxiliary heater in accordance with the above heat exchanger, the ribs in each case are arranged between two neighboring flow devices, for example between neighboring flat tubes. A cooling medium under high pressure flows through the plurality of flat tubes, in conjunction with which an exchange of heat is promoted between the cooling medium and the air surrounding the plurality of flat tubes.

A further preferred embodiment, in the form of a device for the air conditioning of air introduced into the interior of a motor vehicle, exhibits at least a compressor, an auxiliary heater and/or evaporator in accordance with the above preferred embodiment, an expansion valve and a cooler in accordance with the above embodiment.

The compressor and the expansion valve are familiar from the prior art. Also familiar is the fact that the cooling medium is under high pressure in high-pressure cooling circuits, at least in a section of the cooling circuit which extends from an outlet of the compressor via the high-pressure heat exchanger to the

expansion valve.

Further advantages and embodiments of the present invention can be appreciated from the accompanying drawings, in which:

Fig. 1 is a partial representation of a device in accordance with the invention for the exchange of heat, in the form of a heat exchanger for a gas cooler;

Fig. 2 is a representation, which depicts a relationship between geometrical dimensions of the component parts of a device in accordance with the invention for the exchange of heat, in the form of a heat exchanger for a gas cooler;

Fig. 3 is a graphical representation with a relationship between a block depth of a two-row gas cooler with flat tubes in accordance with the invention and a flat tube depth of a tube in accordance with the invention for two bursting pressures;

Fig. 4 is a graphical representation with a relationship between a flat tube depth of a tube in accordance with the invention and a block depth of a two-row gas cooler with flat tubes in accordance with the invention for two bursting pressures;

Fig. 5 is a graphical representation with a relationship between an air face velocity and a gas cooler output for a gas cooler with flat tubes in accordance with the invention and for a comparable gas cooler with twisted flat tubes in accordance with a first gas cooler matrix;

Fig. 6 is a graphical representation with a relationship between an air face velocity and a gas

cooler output for a gas cooler with flat tubes in accordance with the invention and for a comparable gas cooler with twisted flat tubes in accordance with a second gas cooler matrix;

Fig. 7 is a graphical representation with a relationship between a flat tube width and a weight of a gas cooler matrix for different gas cooler matrices;

Fig. 8 is a graphical representation with a relationship between an air face velocity and a weight-related gas cooler output for a gas cooler with flat tubes in accordance with the invention and for a comparable gas cooler with twisted flat tubes in accordance with a first gas cooler matrix;

Fig. 9 is a graphical representation with a relationship between an air face velocity and a weight-related gas cooler output for a gas cooler with flat tubes in accordance with the invention and for a comparable gas cooler with twisted flat tubes in accordance with a second gas cooler matrix;

Fig. 10 is a partial representation of a conventional heat exchanger for a gas cooler having a plurality of conventional twisted flat tubes in accordance with the prior art.

Fig. 1 depicts a section through a two-row high-pressure gas cooler 110, abbreviated here to gas cooler.

The two-row gas cooler 110 in accordance with this embodiment exhibits a tube interconnection from 29/31 - 31/29 and overall dimensions of a heat exchanger matrix in the order of approximately B x H = 462.0 x 660 mm^2. A block depth of the two-row gas cooler

110 is in the order of approximately 16 mm.

In Fig. 1, the reference designation 100 in each case relates to a (flat) tube of the two-row gas cooler 110 in accordance with the invention.

The flat tube 100 exhibits a tube length in the order of approximately 670 mm and a flat tubular cross section 101 with a long side, a flat tube depth of 5.8 mm, and a significantly shorter side, a flat tube width, of 1.5 mm in relation to this long side.

Moreover, the flat tube 100 exhibits a linear course for the tubes over the entire length of the tube along a longitudinal axis of the tube.

In the two-row gas cooler in accordance with the embodiment, the tubes 100 are arranged on two mutually parallel levels 102, 103.

Within each level 102, 103, the flat tubes 100 are also arranged parallel with one another at a distance of approximately 2 mm to 10 mm, preferably between 4 mm and 8 mm, and in particular approximately 6 mm.

Between two flat tubes 100 arranged in each case adjacent to and parallel with one another on a level 102, 103, corrugated ribs 106, in each case with a rib height in the order of approximately 6 mm, are arranged along the length of the tube and in the longitudinal direction 104 of the tubes 100.

The two-row gas cooler 110 in accordance with the embodiment exhibits an overall rib density of 75 ribs/dm. A preferred range for the density of the ribs is in the order of 65 to 85 ribs/dm.

A cooling medium under high pressure flows through the flat tubes 100 in the longitudinal direction 104, for which purpose in the flat tube 100 a plurality of flow channels 105 run essentially parallel with the longitudinal direction 104 and the longitudinal axis of the flat tube 100.

A couple of collection tanks 120 exhibiting two collection tubes 123, 124 are connected to each flat tube end 121 at a connection point provided for the purpose, in order to extend in a direction, a principal direction of extension, perpendicular to the longitudinal direction 104 of each tube 100. A cooling medium under high pressure also flows through these.

Consequently, the flat tubular cross section 101 and the long side of the flat tubular cross section 101 of the tube 100 exhibit, at each connection point, a predetermined angle in the order of approximately 90° in relation to the principal direction of extension of the collection tank 120.

A recess for the connection of the flat tube 100 is provided at the connection point on the side of the collection tank 120. A cross section through the recess is adapted in this case to the cross section 101 of the flat tube 100. In addition, the recess exhibits a supplementary formed area, in the form of a guide taper for the flat tubes 100.

The expression connection to one another is used to denote a connection of a kind such that a fluid in liquid and/or gaseous form, such as the cooling medium in this case, is able to flow through this connection in a liquid-tight and/or gas-tight manner.

Corresponding methods for producing a tight connection of this kind, such as soldering, welding and/or adhesive bonding, or combinations thereof, are familiar from the prior art.

The collection tanks 120 and the collection tubes 123, 1124 in each case exhibit a tubular cross section 122, in conjunction with which an internal diameter 200 of the tubular cross section 122 is approximately equal to the tube depth of the flat tube 100. A collection tube wall thickness 201 is dependent on a stipulated bursting pressure.

Fig. 2 depicts geometrical relationships for he purpose of determining the block depth.

The block depth T(Ges) is determined from:

T(Ges) = 2 * T(Fl) + 2 x d(wall, collection tube) + b(gap),

where T(Fl) is the flat tube depth, d(wall, collection tube) is a wall thickness of a collection tube, and d(gap) is a gap between the two collection tubes.

Fig. 3 is a graphical representation with a relationship between a block depth of a two-row gas cooler with flat tubes in accordance with the invention and a flat tube depth of a flat tube in accordance with the invention for two bursting pressures, namely 270 bar and 360 bar.

The graphical relation depicted here is based on the fact that b(gap) = 0.8 mm, and d(wall, collection tube) is determined by

d(wall, collection tube) = 0.1 x p(burst) * T(Fl)/(2 *

s),

where p(burst) designates the bursting pressure, and s is a limit of elasticity of a collection tube material. s is assumed in the present case to have a value of 50 N/mm^2 (AA 3003 mod).

It can be appreciated from Fig. 3 that the maximum flat tube depth T(Fl) can be = 5.9 mm for a block depth of 16 mm and a bursting pressure of 270 bar. For a bursting pressure of 360 bar, the maximum flat tube depth T(Fl) = 5.5 mm.

The flat tube depth T(Fl) < 6 mm is thus adequate for a bursting pressure of 270 bar for linear flat tubes in the case of two-row high-pressure gas coolers with a block depth of 16 mm.

Consideration must also be given here to the circumstance that, with decreasing flat tube depths T(Fl), a contact surface between a corrugated rib and the flat tube is reduced at a constant block depth. For this reason, at a block depth of 16 mm, the individual flat tube depth should also not be less than approximately 5 mm. Corresponding consideration must also be given to other total block depths.

It can also be appreciated from Fig. 3 that, for a block depth of 14 mm in the case of two-row gas coolers, a flat tube depth T(Fl) < 5.20 mm is adequate for a bursting pressure of 270 bar in the case of linear flat tubes.

Fig. 4 is a graphical representation with a relationship between a flat tube depth of a tube in accordance with the invention and a block depth of a two-row gas cooler with flat tubes in accordance with

the invention for two bursting pressures, namely 270 bar and 360 bar.

It can be appreciated from Fig. 4, for example, that, in the case of a bursting pressure of 270 bar (360 bar) and a block depth of 15 mm, a flat tube depth in the order of approximately 5.2 mm (5.6 mm) is adequate in the case of linear flat tubes.

Figs. 5 and 6 depict a gas cooler output for a gas cooler plotted against an air face velocity under stipulated marginal conditions.

In Fig. 5, 2 two-row high-pressure gas coolers with a rib density of 75 ribs/dm, a rib height of 6 mm, a block depth of 16 mm and identical tube interconnections 29/31 - 31/29 are compared with one another.

Gas cooler 1 exhibits conventional flat tubes with twisted flat tube ends and with a flat tube depth of 7 mm. The dimensions of the heat exchanger matrix of this gas cooler 1 are B x H = 462.0 x 650.0 mm^2 for an end face F(St) = 30.0 dm^2.

Gas cooler 2 exhibits the flat tubes in accordance with the invention with a linear course for the tubes and with a flat tube depth of 5.8 mm. The dimensions of the heat exchanger matrix of the gas cooler 2 are B x H = 462.0 x 664.0 mm^2 for an end face F(St) = 30.7 dm^2.

The larger end face of the gas cooler 2 means that the disadvantage of the smaller flat tube depth and the associated reduced contact surface between the corrugated rib and the flat tube can be more or less equalized. The gas cooler 2 exhibits a greater pressure

drop on the cooling medium side for an identical mass flow rate.

Fig. 6 compares 2 two-row high-pressure gas coolers with a rib density of 75 ribs/dm, a rib height of 4.5 mm, a block depth of 16 mm and identical tube interconnections 37/40 - 40/37 with one another.

Gas cooler 1 exhibits conventional flat tubes with twisted flat tube ends and with a flat tube depth of 7 mm. The dimensions of the heat exchanger matrix of this gas cooler 1 are B x H = 458.8 x 650.0 mm^2 for an end face F(St) = 29.8 dm^2.

Gas cooler 2 exhibits the flat tubes in accordance with the invention with a linear course for the tubes and with a flat tube depth of 5.8 mm. The dimensions of the heat exchanger matrix of the gas cooler 2 are B x H = 458.0 x 664.0 mm^2 for an end face F(St) = 30.5 dm^2.

The larger end face of the gas cooler 2 means that the disadvantage of the smaller flat tube depth and the associated reduced contact surface between the corrugated rib and the flat tube can be more or less equalized. The gas cooler 2 exhibits a higher pressure drop on the cooling medium side for an identical mass flow rate.

Fig. 7 is a graphical representation with a relationship between a flat tube width and a weight of a gas cooler matrix for different gas cooler matrices.

The relationships for a flat tube in accordance with the invention having a flat tube depth of T(Fl) < 6 mm and for a conventional flat tube having a larger flat tube depth, namely T(Fl) = 7 mm are depicted in

Fig. 7.

The relationships are depicted in each case for flat tube widths of 1.4 mm and 1.6 mm and for two corrugated rib heights of 4.5 mm and 6 mm for a rib density of 75 ribs/dm. The thickness of a single corrugated rib is 0.1 mm.

It can be appreciated from Fig. 7 that the weight of gas coolers having a flat tube depth $T(Fl) < 6$ mm in accordance with the invention is significantly smaller.

Figs. 8 and 9 depict a weight-related gas cooler output, which is arrived at by dividing the gas cooler output by the weight of the heat exchanger matrix, and by plotting this against the air face velocity under stipulated marginal conditions.

The gas cooler output depicted here relates to the gas cooler already dealt with in Fig. 5 and Fig. 6.

It can be appreciated from Fig. 8 and Fig. 9 that the weight-related gas cooler output for the two gas coolers with the flat tubes in accordance with the invention having a flat tube depth $T(Fl) < 6.1$ mm is significantly larger in comparison with the two gas coolers with conventional flat tubes having a flat tube depth of 7 mm.

The present invention is particularly suitable for application to the coolers or auxiliary heaters of a high-pressure cooling circuit. A design of the heat exchanger matrix in each case is not restricted to the geometries described above. It can be selected freely in the context of the flat tube geometry in accordance with the invention and the bursting pressure

requirements.

Although the present invention has been explained fully in conjunction with preferred embodiments with reference to the accompanying drawings, numerous variations and modifications will be obvious to a person skilled in the art, all of which come within the scope of the present invention, as laid down in the accompanying patent claims.